Chapter 11
ACCURACY STANDARDS FOR ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT SURVEYING AND MAPPING

11-1. Scope. This chapter provides technical guidance on engineering surveying and mapping accuracy standards used in engineering and construction. It is intended for use in developing specifications for geospatial data used in various project documents, such as architectural and engineering drawings, master planning maps, construction plans, navigation project condition charts and reports, and related GIS, CADD, and AM/FM products. Guidance is provided for preparing specifications for surveying and mapping services.

11-2. General Surveying and Mapping Specifications. Construction plans, maps, facility plans, and CADD/GIS data bases are created by a variety of terrestrial, satellite, acoustic, or aerial mapping techniques that acquire planimetric, topographic, hydrographic, or feature attribute data. Specifications for obtaining these data should be "performance-based" and not overly prescriptive or process oriented. They should be derived from the functional project requirements and use recognized industry accuracy standards where available.

a. Industry standards. Maximum use should be made of industry standards and consensus standards established by private voluntary standards bodies; in lieu of Government-developed standards. Therefore, industry-developed accuracy standards should be given preference over Government standards. A number of professional associations have published surveying and mapping accuracy standards, such as the American Society for Photogrammetry and Remote Sensing (ASPRS), the American Society of Civil Engineers (ASCE), the American Congress on Surveying and Mapping (ACSM), and the American Land Title Association (ALTA). When industry standards are non-existent, inappropriate, or do not meet a project's functional requirement, FGDC, DoD, Tri-Service, DA, or USACE standards may be specified as criteria sources. Minimum technical standards established by state boards of registration, especially on projects requiring licensed surveyors or mappers, should be followed when legally applicable. Local surveying and mapping standards should not be developed where consensus industry standards or DoD/DA standards exist.

b. Performance specifications. Performance-oriented (i.e., outcome based) specifications are recommended in procuring surveying and mapping services. Performance specifications set forth the end results to be achieved (i.e., final map format, data content, and/or accuracy standard) and <u>not</u> the means, or technical procedures, used to achieve those results. Performance-oriented specifications typically provide the most flexibility and use of state-of-the-art instrumentation and techniques. Performance specifications should succinctly define only the basic mapping requirements that will be used to verify conformance with the specified criteria, e.g., mapping limits, feature location and attribute requirements, scale, contour interval, map format, sheet layout, and final data transmittal, archiving or storage requirements, required accuracy criteria standards for topographic and planimetric features that are to be depicted, and quality assurance procedures. Performance-oriented specifications should be free from unnecessary equipment, personnel, instrumentation, procedural, or material limitations; except as needed to establish comparative cost estimates for negotiated services.

c. Prescriptive (procedural) specifications. Use of prescriptive specifications should be kept to a minimum, and called for only on highly specialized or critical projects where only one prescribed technical method is appropriate or practical to perform the work. Prescriptive specifications typically require specific field instrumentation, equipment, personnel, office technical production procedures, or rigid project phasing with on-going design or construction. Prescriptive specifications may, depending on the expertise of the writer, reduce flexibility, efficiency, and risk, and can adversely impact project costs if antiquated methods or instrumentation are required. Prescriptive specifications also tend to shift most liability to the Government. Occasionally, prescriptive specifications may be applicable to Corps projects involving specialized work not routinely performed by private surveying and mapping firms, e.g., mapping tactical operation sites, mapping hazardous, toxic, and radioactive waste (HTRW) clean-up sites, military/tactical surveying, or structural deformation monitoring of locks, dams, and other flood control structures.

d. Tri-Service CADD/GIS Technology Center standards. Tri-Service standards should be specified for in-house or A-E services requiring delivery of CADD, GIS, and other spatial and geospatial data covered by this chapter--see Chapter 7 for detailed reference requirements.

e. Quality control. Quality control (QC) of contracted surveying and mapping work should generally be performed by the contractor. Therefore, USACE quality assurance (QA) and testing functions should be focused on whether the contractor meets the required performance specification (e.g., accuracy standard), and not the intermediate surveying, mapping, and compilation steps performed by the contractor. The contractor's internal QC will normally include independent tests which may be periodically reviewed by the Government. Government-performed (or monitored) field testing of map accuracies is an optional QA requirement, and should be performed when technically and economically justified, as determined by the ultimate project function.

f. Metrication. Surveying and mapping performed for design and construction should be recorded and plotted in the units prescribed for the project by the requesting Command or project sponsor. During transition to the metric system, inch-pound (IP) units or soft conversions may be required for some geospatial data.

g. Spatial coordinate reference systems. Where practical and feasible, civil and military projects should be adequately referenced to nationwide or worldwide coordinate systems directly derived from, or indirectly connected to, Global Positioning System (GPS) satellite observations. In addition, navigation and flood control projects in tidal areas should be vertically referenced to the latest datum epoch established by the Department of Commerce.

11-3. <u>Accuracy Standards for Engineering and Construction Surveying</u>. Engineering and construction surveys are performed to locate, align, and stake out construction for civil and military projects, e.g., buildings, utilities, roadways, runways, flood control and navigation projects, training ranges, etc. Engineering surveys are performed to provide the base horizontal and vertical control used for area mapping, GIS development, preliminary planning studies, detailed site plan drawings for construction plans, construction measurement and payment, preparing as-built drawings, installation master planning mapping, and future maintenance and repair activities. Most engineering surveying standards currently used are based on local practice, or may be contained in State minimum technical standards.

a. Accuracy standards. Engineering and construction surveys are normally specified and classified based on the horizontal (linear) point closure ratio or a vertical elevation difference closure standard. This type of performance criteria is most commonly specified in Federal agency, state, and local surveying standards, and should be followed and specified by USACE commands. These standards are applicable to most types of engineering and construction survey equipment and practices (e.g., total station traverses, differential GPS, differential spirit leveling). These accuracy standards are summarized in the following tables.

Table 11-1
Minimum Closure Accuracy Standards for Engineering and Construction Surveys

USACE Classification	Closure Standard	
Engr & Const Control	Distance (Ratio)	Angle (Secs)
First-Order	1:100,000	$2\sqrt{N}$[1]
Second-Order, Class I	1:50,000	$3\sqrt{N}$
Second-Order, Class II	1:20,000	$5\sqrt{N}$
Third-Order, Class I	1:10,000	$10\sqrt{N}$
Third-Order, Class II	1: 5,000	$20\sqrt{N}$
Engineering Construction (Fourth-Order)	1: 2,500	$60\sqrt{N}$

[1] N = Number of angle stations

Table 11-2
Minimum Elevation Closure Accuracy Standards for Engineering and Construction Surveys

USACE Classification	Elevation Closure Standard (ft)[1]	(mm)
First-Order, Class I	$0.013\sqrt{M}$	$3\sqrt{K}$
First-Order, Class II	$0.017\sqrt{M}$	$4\sqrt{K}$
Second-Order, Class I	$0.025\sqrt{M}$	$6\sqrt{K}$
Second-Order, Class II	$0.035\sqrt{M}$	$8\sqrt{K}$
Third-Order	$0.050\sqrt{M}$	$12\sqrt{K}$
Construction Layout	$0.100\sqrt{M}$	$24\sqrt{K}$

[1] $\sqrt{M}$ or $\sqrt{K}$ = square root of distance in Miles or Kilometers

b. Survey closure standards. Survey closure standards listed in Tables 11-1 and 11-2 should be used as a basis for classifying, standardizing, and evaluating survey work. The point and angular closures (i.e., traverse misclosures) relate to the relative accuracy derived from a particular survey. This relative accuracy (or, more correctly, precision) is estimated based on internal closure checks of a traverse survey run through the local project, map, land tract, or construction site. Relative survey accuracy estimates are always expressed as ratios of the traverse/loop closure to the total length of the survey (e.g., 1:10,000).

(1) Horizontal closure standard. The horizontal point closure ratio is determined by dividing the linear distance misclosure of the survey into the overall circuit length of a traverse, loop, or network line/circuit. When independent directions or angles are observed, as on a conventional traverse or closed loop survey, these angular misclosures should be distributed (balanced) before assessing positional misclosure. In cases where differential GPS vectors are measured in three-dimensional geocentric coordinates, then the horizontal component of position misclosure is assessed relative to Table 11-1.

(2) Vertical control standards. The vertical accuracy of a survey is determined by the elevation misclosure within a level

section or level loop. For conventional differential or trigonometric leveling, section or loop misclosures (in millimeters or feet) should not exceed the limits shown in Table 11-2, where the line or circuit length is measured in the applicable units. Fourth-Order accuracies are intended for construction layout grading work.

c. Geospatial Positioning Accuracy Standards. Many control surveys are now being efficiently and accurately performed using radial (spur) techniques--e.g., single line vectors from electronic total stations or kinematic differential GPS to monumented control points, topographic feature points, property corners, etc. Since these surveys may not always result in loop closures (i.e., closed traverse) alternative specifications for these techniques must be allowed. This is usually done by specifying a radial positional accuracy requirement. The required positional accuracy may be estimated based on the accuracy of the fixed reference point, instrument, and techniques used. Ratio closure standards in Tables 11-1 and 11-2 may slowly decline as more use is made of nation-wide augmented differential GPS positioning and electronic total station survey methods. The FGDC is currently (1998) proposing use of positional accuracy tolerances in order to more easily correlate surveying standards with mapping or geospatial positional accuracy standards--e.g., NSSDA.

(1) GPS satellite positioning technology allows development of map features to varying levels of accuracy, depending on the type of equipment and procedures employed. Given this rapidly developing technology, GPS surveying specifications rapidly become obsolete; therefore, it is best to follow GPS manufacturer's recommended procedures. The advent of Government and commercial augmented GPS systems allows direct, near real-time positioning of static AM/FM type features and dynamic platforms (survey vessels, aircraft, etc.). Site plan drawings, photogrammetric control, and related GIS features can be directly constructed from GPS or differential GPS observations, at accuracies ranging from 1 cm to 100 meters (95%).

(2) Accuracy classifications of maps and related GIS data developed by GPS methods can be estimated based on the GPS positioning technique employed. Permanent GPS reference stations (Continuously Operating Reference Stations or CORS) can provide decimeter and even centimeter-level point positioning accuracies

over wide ranges; thus providing direct map/feature point positioning without need for preliminary control surveys.

d. Higher-order surveys. Requirements for relative line accuracies exceeding 1:50,000 are rare for most facility engineering, construction, or mapping applications. Surveys requiring accuracies of First-Order (1:100,000) or better should be performed using FGDC geodetic standards and specifications. These surveys must be adjusted and/or evaluated by the National Geodetic Survey (NGS) if official certification relative to the national network is required.

e. Instrumentation and field observing criteria. In accordance with the policy to use performance-based standards, rigid prescriptive requirements for survey equipment, instruments, or operating procedures are discouraged. Survey alignment, orientation, and observing criteria should rarely be rigidly specified; however, general guidance regarding limits on numbers of traverse stations, minimum traverse course lengths, auxiliary azimuth connections, etc., may be provided for information. For some highly specialized work, such as dam monitoring surveys, technical specifications may prescribe that a general type of instrument system be employed, along with any unique operating, calibration, or recordation requirements.

f. Connections to existing control. Surveys should normally be connected to existing local control or project control monuments/benchmarks. These existing points may be those of any Federal (including Corps project control), State, local, or private agency. Ties to local Corps or installation project control and boundary monuments are absolutely essential and critical to design, construction, and real estate. In order to minimize scale or orientation errors, at least two existing monuments should be connected. It is recommended that Corps surveys be connected with one or more stations on the National Spatial Reference System (NSRS), when practicable and feasible. Connections with local project control that has previously been connected to the NSRS is normally adequate in most cases. Connections with the NSRS shall be subordinate to the requirements for connections with local/project control.

g. Survey computations, adjustments and quality control/assurance. Survey computations, adjustments, and quality control should be performed by the organization responsible for the actual field survey. Contract compliance assessment of a survey should be based on the prescribed point closure standards of internal loops, not on closures with external networks of unknown accuracy. In cases where internal loops are not observed, then assessment must be based on external closures. Specifications should not require closure accuracy standards in excess of those required for the project, regardless of the accuracy capabilities of the survey equipment. Least squares adjustment methods should be optional for 2nd or lower order survey work. Professional contractors should not be restricted to rigid computational methods, software, or recording forms. Use of commercial software adjustment packages is strongly recommended.

h. Data recording and archiving. Field survey data may be recorded and submitted either manually or electronically. Manual recordation should follow standard industry practice, using field book formats outlined in various technical manuals.

11-4. Accuracy Standards for Maps and Related Geospatial Products. Map accuracies are defined by the positional accuracy of a particular graphical or spatial features depicted. A map accuracy standard classifies a map as statistically meeting a certain level of accuracy. For most engineering projects, the desired accuracy is stated in the specifications, usually based on the final development scale of the map--both the horizontal "target" scale and vertical relief (specified contour interval or digital elevation model). Often, however, in developing engineering plans, spatial data bases may be developed from a variety of existing source data products, each with differing accuracies--e.g., mixing 1 in = 60 ft topo plans with 1 in = 400 ft reconnaissance topo mapping. Defining an "accuracy standard" for such a mixed data bases is difficult and requires retention of the source of each data feature in the base. In such cases the developer must estimate the accuracy of the mapped features.

a. ASPRS Standard. For site mapping of new engineering or planning projects, there are a number of industry and Federal mapping standards that may be referenced in contract specifications. The recommended standard for facility engineering is the ASPRS "Accuracy Standards for Large-Scale Maps" (ASPRS 1990). This standard, like most other mapping standards, defines map accuracy by comparing the mapped location of selected well-defined points to their "true" location, as determined by a more accurate, independent field survey. Alternately, when no independent check is feasible or practicable, a map's accuracy may be estimated based on the accuracy of the technique used to locate mapped features--e.g., photogrammetry, GPS, total station, plane table, The ASPRS standard has application to different types of mapping, ranging from wide-area, small-scale, GIS mapping to large-scale construction site plans. It is applicable to all types of horizontal and vertical geospatial mapping derived from conventional topographic surveying or photogrammetric surveys. This standard may be specified for detailed construction site plans that are developed using conventional ground topographic surveying techniques (i.e., electronic total stations, plane tables, kinematic GPS). The ASPRS standard is especially applicable to site plan development work involving mapping scales larger than 1:20,000 (1 in. = 1,667 ft); it therefore applies to the more typical engineering map scales in the 1:240 (1 in. = 20 ft) to 1:4,8000 (1 in. = 400 ft) range. Its primary advantage over other standards is that it contains more definitive statistical map testing criteria, which, from a contract administration standpoint, is desirable. Using the guidance in Tables 11-3 and 11-4, specifications for site plans need only indicate the ASPRS map class, target scale, and contour interval.

b. Horizontal (planimetric) accuracy criteria. The ASPRS planimetric standard compares the root mean square error (RMSE) of the average of the squared discrepancies, or differences in coordinate values between the map and an independent topographic ground survey of higher accuracy (i.e., check survey). The "limiting RMSE" is defined in terms of meters (feet) at the ground scale rather than in millimeters (inches) at the target map scale. This results in a linear relationship between RMSE and target map scale; as map scale decreases, the RMSE increases linearly. The RMSE is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation, and final extraction of ground dimensions from the target map. The limiting RMSE's shown in Table 11-3 are the maximum permissible RMSE's established by the ASPRS standard. These ASPRS limits of accuracy apply to well-defined map test points only--and only at the specified map scale.

c. Vertical (topographic) accuracy criteria. Vertical accuracy has traditionally been, and currently still is, defined relative to the required contour interval for a map. In cases where digital elevation models (DEM) or digital terrain models (DTM) are being generated, an equivalent contour interval can be specified, based on the required digital point/spot elevation accuracy. The contours themselves may be later generated from a DEM using computer software routines. The ASPRS vertical standard also uses the RMSE statistic, but only for well-defined features between contours containing interpretative elevations, or spot elevation points. The limiting RMSE for Class 1 contours is one-third of the contour interval. Testing for vertical map compliance is also performed by independent, equal, or higher accuracy ground survey methods, such as differential leveling. Table 11-4 summarizes the limiting vertical RMSE for well-defined points, as checked by independent surveys at the full (ground) scale of the map.

Table 11-3a. ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Meters) for Well-Defined Points

Target Map Scale	ASPRS Limiting RMSE in X or Y (Meters)		
Ratio m/m	Class 1	Class 2	Class 3
1:50	0.0125	0.025	0.038
1:100	0.025	0.05	0.075
1:200	0.050	0.10	0.15
1:500	0.125	0.25	0.375
1:1,000	0.25	0.50	0.75
1:2,000	0.50	1.00	1.5
1:2,500	0.63	1.25	1.9
1:4,000	1.0	2.0	3.0
1:5,000	1.25	2.5	3.75
1:8,000	2.0	4.0	6.0
1:10,000	2.5	5.0	7.5
1:16,000	4.0	8.0	12.0
1:20,000	5.0	10.0	15.0
1:25,000	6.25	12.5	18.75
1:50,000	12.5	25.0	37.5
1:100,000	25.0	50.0	75.0
1:250,000	62.5	125.0	187.5

Table 11-3b. ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Feet) for Well-Defined Points

Target Map Scale		ASPRS Limiting RMSE in X or Y (Feet)		
1"= x ft	Ratio ft/ft	Class 1	Class 2	Class 3
5	1:60	0.05	0.10	0.15
10	1:120	0.10	0.20	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1,000	1:12,000	10.0	20.0	30.0
1,667	1:20,000	16.7	33.3	50.0

Table 11-4a. ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points (Meters)

ASPRS Limiting RMSE in Meters

Target Contour Interval	Spot or Digital Topographic Feature Points			Terrain Model Elevation Points		
Meters	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.10	0.03	0.07	0.10	0.02	0.03	0.05
0.20	0.07	0.13	0.2	0.03	0.07	0.10
0.25	0.08	0.17	0.25	0.04	0.08	0.12
0.5	0.17	0.33	0.50	0.08	0.16	0.25
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5
10	3.33	6.67	10.0	1.67	3.33	5.0

Table 11-4b. ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points (Feet)

ASPRS Limiting RMSE in Feet						
Target Contour Interval	Topographic Feature Points			Spot or Digital Terrain Model Elevation Points		
ft	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.5	0.17	0.33	0.50	0.08	0.16	0.2
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5

d. Map accuracy quality assurance testing and certification. Independent map testing is a quality assurance function that is performed independent of normal quality control during the mapping process. Specifications and/or contract provisions should indicate the requirement (or option) to perform independent map testing. Independent map testing is rarely performed for engineering and construction surveys. If performed, map testing should be completed within a fixed time period after delivery, and if performed by contract, after proper notification to the contractor. In accordance with the ASPRS standard, the horizontal and vertical accuracy of a map is checked by comparing measured coordinates or elevations from the map (at its intended target scale) with spatial values determined by a check survey of higher accuracy. The check survey should be at least twice (preferably three times) as accurate as the map feature tolerance given in the ASPRS tables, and a minimum of 20 points tested. Maps and related geospatial databases found to comply with a particular ASPRS standard should have a statement indicating that standard. The compliance statement should refer to the data of lowest accuracy depicted on the map, or, in some instances, to specific data layers or levels. The statement should clearly indicate the target map scale at which the map or feature layer was developed. When independent testing is not performed, the compliance statement should clearly indicate that the procedural mapping specifications were designed and performed to meet a certain ASPRS map classification, but that a rigid compliance test was not performed. Published maps and geospatial databases whose errors exceed those given in a standard should indicate in their legends or metadata files that the map is not controlled and that dimensions are not to scale. This accuracy statement requirement is especially applicable to GIS databases that may be compiled from a variety of sources containing known or unknown accuracy reliability.

e. National Standard for Spatial Data Accuracy (NSSDA). The traditional small-scale "United States National Map Accuracy Standard" (Bureau of the Budget 1947) is currently (1998) being revised by the FGDC as the NSSDA. The latest draft of the NSSDA indicates it is directly based on the ASPRS standard; however, the ASPRS coordinate-based standard is converted to a 95% radial error statistic and the vertical standard is likewise converted from a one-sigma (68%) to 95% standard. The draft NSSDA defines positional accuracy of spatial data, in both digital and graphic form, as derived from sources such as aerial photographs, satellite imagery, or other maps. Its purpose is to facilitate the identification and application of spatial data by implementing a well-defined statistic (i.e., 95% confidence level) and testing methodology. As in the ASPRS standard, accuracy is assessed by comparing the positions of well defined data points with positions determined by higher accuracy methods, such as ground surveys. Unlike the above ASPRS tables, the draft NSSDA standard does not define pass-fail criteria--data and map producers must determine what accuracy exists for their data. Users of that data determine what constitutes acceptable accuracies for their applications. Unlike the ASPRS standard which uses the RMSE statistic in the X, Y, and Z planes, the NSSDA defines horizontal spatial accuracy by circular error of a data set's horizontal (X & Y) coordinates at the 95% confidence level. Vertical spatial data is defined by linear error of a data set's vertical (Z) coordinates at the 95% confidence level. ASPRS lineal horizontal accuracies in X and Y can be converted to NSSDA radial accuracy by multiplying the limiting RMSE values in Table 3 by 2.447, e.g.,

$$\text{Radial Accuracy}_{NSSDA} = 2.447 * \text{RMSE}_{ASPRS\text{-- } X \text{ or } Y} \qquad \text{Eq. 11-1}$$

ASPRS 1-sigma (68%) vertical accuracies can be converted to NSSDA 95% lineal accuracy by multiplying the limiting RMSE values in Table 4 by 1.96, e.g.,

$$\text{Vertical Accuracy}_{NSSDA} = 1.96 * \text{RMSE}_{ASPRS\text{ -- }Z} \qquad \text{Eq. 11-2}$$

In time, it is expected that the NSSDA will be the recognized standard for specifying the accuracy of all mapping and spatial data products, and the ASPRS standard will be modified to 95% confidence level specifications.

f. Other mapping standards. When work is performed for DoD tactical elements or other Federal agencies or overseas, mapping standards other than ASPRS may be required.

11-5. Topographic and Site Plan Survey Standards. Topographic surveys and construction site plan surveys are performed for the master planning, design, and construction of installations, buildings, housing complexes, roadways, airport facilities, flood control structures, navigation locks, etc. Construction plans are performed at relatively large scales (typically ranging between 1" = 20 ft to 1" = 400 ft (1:240 to 1:4,800)) using electronic total stations, plane tables, or other terrestrial survey techniques. The ASPRS large scale mapping accuracy standards may be used for all types of ground topographic surveying methods. Guidance for performing topographic surveys is contained in a variety of commercial and government publications. Recognized industry procedural specifications, manuals, or surveying textbooks should be used for guidance in performing plane table surveys, total station surveys, and radial topographic mapping methods using kinematic GPS. For all types of topographic surveys or site plan surveys, the mapping specifications must clearly indicate the level of surface and underground feature detail to be mapped. Recommended detail scales for common types of engineering plans and topographic maps are outlined below and at the end of this chapter. Refer also to EM 1110-1-1005, Topographic Mapping.

a. Reconnaissance topographic surveys. These surveys are performed at relatively small scales--from 1" = 400 ft (1:4,800) to 1" = 1,000 ft (1:12,000). They provide a basis for general studies, site suitability decisions, or preliminary site layouts. General location of existing roads and facilities are depicted, and only limited feature and rough elevation detail is shown--5 to 10 foot contour intervals usually being adequate. Enlarged USGS 1:24,000 maps may be substituted in many cases.

b. General/Preliminary site plans. Scales from 1" = 200 ft to 1" = 400 ft (1:2,400-1:4,800). Depicts general layout arrangement of areas where construction will take place, proposed transportation systems, training areas, and existing facilities.

c. Detailed topographic surveys for construction site plan drawings. Scales from 1" = 20 ft to 1" = 200 ft--and 1 or 2-foot contour intervals. Detailed ground topographic surveys are performed to prepare base map for detailed site plans (general site layout plan, utility plan, grading plan, paving plan, airfield plan, demolition plan, etc.). Scope of mapping confined to existing/proposed building area. Used as base for subsequent as-built drawings of facilities and utility layout maps (i.e., AM/FM data bases).

d. As-Built surveys and AM/FM mapping. As-built drawings may require topographic surveys of constructed features, especially when field modifications are made to original designs. These surveys, along with original construction site plans, should be used as a base framework for an installation's AM/FM data base. Periodic topographic surveys may also be required during maintenance and repair projects in order to update the AM/FM data base.

11-6. Photogrammetric Mapping Standards and Specifications. Most smaller scale (i.e., less than 1 in = 100 ft, or 1:1,200) engineering topographic mapping and GIS data base development is accomplished by aerial mapping techniques. The ASPRS standards should be used in specifying photogrammetric mapping accuracy requirements. Procedures for developing photogrammetric mapping specifications are contained in EM 1110-1-1000, "Photogrammetric Mapping." This manual contains guidance on specifying flight altitudes, determining target scales, and photogrammetric mapping cost estimating techniques. A full contract guide specification is also contained in an appendix to the manual. More comprehensive technical guidance may be obtained from various academic publications. Currently, few aerial mapping references reflect the latest uses and potential efficiencies of GPS-controlled photogrammetry or soft copy compilation processes. In specifying photogrammetric mapping services, it is essential that feature accuracy tolerances (horizontal and vertical) be clearly identified relative to the project target mapping scale, and that this scale be correlated with an appropriate flight altitude and the type of photogrammetric mensuration instruments used.

11-7. Construction Survey Accuracy Standards. Construction survey procedural and accuracy specifications should follow recognized industry and local practices. General procedural guidance is contained in a number of standard commercial texts. Accuracy standards for construction surveys will vary with the type of construction, and may range from a minimum of 1:2,500 up to 1:20,000. A 1:2,500 "4th Order Construction" classification is intended to cover temporary control used for alignment, grading, and measurement of various types of construction, and some local site plan topographic mapping or photo mapping control work. Lower accuracies (1:2,500-1:5,000) are acceptable for earthwork, dredging, embankment, beach fill, and levee alignment stakeout and grading, and some site plan, curb and gutter, utility building foundation, sidewalk, and small roadway stakeout. Moderate accuracies (1:5,000) are used in most pipeline, sewer, culvert, catch basin, and manhole stakeouts, and for general residential building foundation and footing construction, major highway pavement, and concrete runway stakeout work. Somewhat higher accuracies (1:10,000-1:20,000) are used for aligning longer bridge spans, tunnels, and large commercial structures. For extensive bridge or tunnel projects, 1:50,000 or even 1:100,000 relative accuracy alignment work may be required. Grade elevations are usually observed to the nearest 0.01 foot for most construction work, although 0.1 ft accuracy is sufficient for riprap placement, earthwork grading, and small-diameter pipe placement. Construction control points are typically marked by semi-permanent or temporary monuments (e.g., plastic hubs, P-K nails, iron pipes, wooden grade stakes).

11-8. Cadastral or Real Property Survey Accuracy Standards.

a. General. Many State codes, rules, statutes or general professional practices prescribe minimum technical standards for real property surveys. Corps in-house surveyors or contractors should follow applicable State technical standards for real property surveys involving the determination of the perimeters of a parcel or tract of land by establishing or reestablishing corners, monuments, and boundary lines, for the purpose of describing, locating fixed improvements, or platting or dividing parcels. Although some State standards relate primarily to accuracies of land and boundary surveys, other types of survey work may also be covered in some areas. Refer to ER 405-1-12, Real Estate Handbook and the "Manual of Instructions for the Survey of the Public Lands of the United States" (US Bureau of Land Management 1973) for additional technical guidance on performing cadastral surveys, or surveys of private lands abutting or adjoining Government lands.

b. ALTA/ACSM standards. Real property survey accuracy standards recommended by ALTA/ACSM are contained in "Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys," 1992. This standard was developed to provide a consistent national standard for land title surveys and may be used as a guide in specifying accuracy closure requirements for USACE real property surveys. However, it should be noted that the ALTA/ACSM standard itself not only prescribes closure accuracies for land use classifications but also addresses specific needs peculiar to land title insurance matters. The standards contain requirements for detailed information and certification pertaining to land title insurance, including information discoverable from the survey and inspection that may not be evidenced by the public records. The standard also contains a table as to optional survey responsibilities and specifications which the title insurer may require. USACE cadastral surveys not involving title insurance should follow State minimum standards; not ALTA/ACSM standards. On land acquisition surveys which may require title insurance, the decision to perform an ALTA/ACSM standard survey, including all optional survey responsibilities and specifications, should come from the project sponsor. Meeting ALTA/ACSM Urban Class accuracy standards is considered impractical for small tracts or parcels less than 1 acre in size.

11-9. Hydrographic Surveying Accuracy Standards. Hydrographic surveys are performed for a variety of engineering, construction, and dredging applications in USACE. Accuracy standards, procedural specifications, and related technical guidance are contained in EM 1110-2-1003, Hydrographic Surveying. This manual should be attached to any A-E contract containing hydrographic surveying work, and must be referenced in construction dredging contracts involving in-place measurement and payment. Standards in this manual apply to Corps river and harbor navigation project surveys, such as dredge measurement and payment surveys, channel condition surveys of inland and coastal Federal navigation projects, beach renourishment surveys, and surveys of other types of marine structures. Accuracy standards for three distinct classes of surveys are specified: (1) Contract Payment, (2) Project Condition, and (3) Reconnaissance Surveys. Standards for nautical charting surveys or deep-water bathymetric charting surveys should conform with applicable Defense Mapping Agency (DMA), National Ocean Survey (NOS), or U.S. Naval Oceanographic Office (USNAVOCEANO) accuracy and chart symbolization criteria.

11-10. Structural Deformation Survey Standards. Deformation monitoring surveys of Corps structures require high line vector and/or positional accuracies to monitor the relative movement of monoliths, walls, embankments, etc. Deformation monitoring survey accuracy standards vary with the type of construction, structural stability, failure probability and impact, etc. Since many periodic surveys are intended to measure "long-term" (i.e., monthly or yearly changes) deformations relative to a stable network, lesser survey precisions are required than those needed for short-term structural deflection type measurements. Long-term structural movements measured from points external to the structure may be tabulated or plotted in either X-Y-Z or by single vector movement normal to a potential failure plane. Accuracy standards and procedures for structural deformation surveys are contained in EM 1110-1-1004. Horizontal and vertical deformation monitoring survey procedures are performed relative to a control network established for the structure. Ties to the National Spatial Reference System are not necessary other than for general reference, and then need only USACE Third-Order connection.

11-11. Geodetic Control Survey Standards. Geodetic control surveys are usually performed for the purpose of establishing a basic framework of the National Spatial Reference System (NSRS). These geodetic network densification survey functions are clearly distinct from the traditional engineering and construction surveying and mapping standards covered in this chapter. Geodetic control surveys of permanently monumented control points that are incorporated in the NSRS must be performed to far more rigorous standards and specifications than are control surveys used for general engineering, construction, mapping, or cadastral purposes. When a project requires NSRS densification, or such densification is a desirable by-product and is economically justified, USACE Commands should conform with published FGDC survey standards and specifications. This includes related automated data recording, submittal, project review, and adjustment requirements mandated by FGDC and the National Geodetic Survey.

11-12. Determining Surveying and Mapping Requirements for Engineering Projects. General guidance for determining project-specific mapping requirements is contained in Table 11-5 at the end of this chapter. This table may be used to develop specifications for map scales, feature location tolerances, and contour intervals for typical engineering and construction projects. It is absolutely essential that surveying and mapping specifications originate from the functional requirements of the project, and that these requirements be realistic and economical. Specifying map scales or accuracies in excess of those required for project planning, design, or construction results in increased costs to USACE, local sponsors, or installations, and may delay project completion. However, the recommended standards and accuracy tolerances shown in Table 11-5 should be considered as general guidance for typical projects--variance from these norms is expected.

a. Mapping scope/limits. Mapping limits should be delineated so only areas critical to the project are covered by detailed ground or aerial surveying. The areal extent of detailed (i.e., large-scale) site plan surveys should be kept to a minimum and confined to the actual building, utility corridor, or structure area. Outside critical construction perimeters, more economical smaller scale plans should be used, along with more relaxed feature location accuracies, larger contour intervals, etc.

b. Target scale and contour interval specifications. Table 11-5 provides recommended map scales and contour intervals for a variety of engineering applications. The selected target scale for a map or construction plan should be based on the detail necessary to portray the project site. Surveying and mapping costs typically increase exponentially with larger mapping scales; therefore, specifying too large a site plan scale or too small a contour interval than needed to adequately depict the site can significantly increase project costs. Topographic elevation density or related contour intervals must be specified consistent with existing site gradients and the accuracy needed to define site layout, drainage, grading, etc., or perform quantity take offs. Photogrammetric mapping flight altitudes or ground topographic survey accuracy and density requirements are determined from the design map target scale and contour interval provided in the contract specifications.

c. Feature location tolerances. This requirement establishes the primary surveying effort necessary to delineate physical features on the ground. In most instances, a construction feature may need to be located to an accuracy well in excess of its plotted/scaled accuracy on a construction site plan; therefore, feature location tolerances should not be used to determine the required scale of a drawing or determine photogrammetric mapping requirements. In such instances, surveyed coordinates, internal CADD grid coordinates, or rigid relative dimensions are used. Table 11-5 indicates recommended positional tolerances (or precisions) of planimetric features. These feature tolerances are defined relative to adjacent points within the confines of a specific area, map sheet, or structure--not to the overall project or installation boundaries. Relative accuracies are determined between two points that must functionally maintain a given accuracy tolerance between themselves, such as adjacent property corners; adjacent utility lines; adjoining buildings, bridge piers, approaches, or abutments; overall building or structure site construction limits; runway ends; catch basins; levee baseline sections; etc. Feature tolerances should be determined from the functional requirements of the project/structure (e.g., field construction/fabrication, field stakeout or layout, alignment, locationing, etc.). Few engineering, construction, or real estate projects require that relative accuracies be rigidly maintained beyond a 1500m (5,000-ft) range, and usually only within the range of the detailed design drawing for a project/structure (or its equivalent CADD design file limit). For example, two catch basins 60 m (200 ft) apart might need to be located to 25mm (0.1 ft) relative to each other, but need only be known to ±30m (±100 ft) relative to another catch basin 10 km (6 miles) away. Likewise, relative accuracy tolerances are far less critical for small-scale GIS data elements. Actual construction alignment and grade stakeout will generally be performed to the 30mm (0.1 ft) or 3mm (0.01 ft) levels, depending on the type of construction.

d. CADD level/layer descriptors. The use of CADD or GIS equipment allows planimetric features and topographic elevations to be readily separated onto various levels or layers and depicted at any scale. Problems may arise when scales are increased beyond their originally specified values, or when so-called "rubber sheeting" is performed. It is therefore critical that these geospatial data layers, and related metadata files, contain descriptor information identifying the original source target scale and designed accuracy.

e. Map control survey specifications. The control survey used to provide primary reference for a map or GIS product is normally performed at a higher accuracy than that required for features shown on the map. Most maps warranting an accuracy classification should be referenced to, or controlled by, conventional field surveys of Third-order accuracy. Control survey accuracies are usually measured in different units--relative distance ratios--rather than positional tolerance. Base- or area-wide mapping control procedures should be designed and specified to meet functional accuracy tolerances within the limits of the structure, building, or utility distance involved for design, construction, or real estate surveys. Higher order (i.e., First or Second-order) control surveys should not be specified for area-wide mapping or GIS definition unless a definitive functional requirement exists (e.g., military operational targeting or some low-gradient flood control projects).

f. Reference datum and coordinate system specifications. A variety of reference datums and coordinate references are used throughout Corps projects. Wide-area mapping projects should be referenced to spatial datums, plane coordinate grids, and vertical reference planes that are commonly used in the area, where practical and feasible. Small, local construction projects and cadastral surveys are usually locally referenced and need not be connected to external datums.

(1) Horizontal reference. In CONUS, maps should be horizontally referenced to either the North American Datum of 1983 (NAD 83) or 1927 (NAD 27) systems. Commands should develop plans to eventually reference all civil and military projects to the NAD 83, with connection to the GPS-based, nationwide National Spatial Reference System (NSRS) if practicable and feasible. These spatial datum coordinates should be transformed to a recognized plane coordinate system that is used in the project or installation area, such as the State Plane Coordinate System (SPCS) or Universal Transverse Mercator (UTM) grid system. The UTM grid system may be used for military operational or tactical uses in locales within and outside the continental United States (OCONUS), or on some civil projects encompassing or crossing multiple SPCS zones. Grid systems (and north arrow references) shown on maps or plans must clearly indicate the reference datum and orientation origin. When local grid systems (e.g., station-offset) are developed for detailed construction, they should be clearly distinguished from the SPCS grid.

(2) Vertical reference. In CONUS, vertical map control should be referenced to either the National Geodetic Vertical Datum, 1929 Adjustment (NGVD 29), or the North American Vertical Datum, 1988 Adjustment (NAVD 88). Independent or local survey datums and reference systems should be avoided unless required by local code, statute, or practice. Coastal navigation projects should be referenced to Mean Lower Low Water (MLLW) datum. Inland low water reference planes should be referenced to NGVD 29 or NAVD 88.

g. Plan drawing feature specifications. Mapping specifications must clearly and explicitly define the types, areal extent, and locational accuracy of features to be surveyed. The type and purpose of the map (e.g., paving plan, landscape plan, irrigation plan, etc.) should be clearly defined in the specifications in order for the field surveyor to determine which features are critical to the project. Especially critical areas, structures, or utilities should be highlighted in the technical requirements, including special accuracy tolerances for these features that may necessitate specialized ground surveying procedures. In addition, the specifications should indicate the symbology, detailing, and attributing required for recurring features, such as manholes, curbs, pavements, valves, etc. Feature symbology/delineation is specified as a function of scale--e.g., depiction of structure perimeters, centerlines, elevations, etc. For each map product, feature depiction, delineation, layering, and attributing requirements should be broken out and specified, generally following the Tri-Service discipline/drawing-based level/layer assignments or, for GIS applications, the entity set, class, attribute and domain relationships. Not all CADD levels/layers will require topographic mapping support--e.g., Interior Design. Within each level/layer, a few of the construction plans are listed below that may require field or aerial topographic mapping to delineate the features or systems on that plan. Typical features or systems within a CADD level/layer construction plan are also listed; however, this listing is not comprehensive and must be adjusted and supplemented for unique project-specific requirements, and to insure features are mapped into appropriate layers with sufficient attribute detail, as explained above.

11-13. <u>References</u>.

ER 405-1-12
Real Estate Handbook

EM 1110-1-1000
Photogrammetric Mapping

EM 1110-1-1004
Deformation Monitoring and Control Surveying

EM 1110-1-1005
Topographic Surveying

EM 1110-2-1003
Hydrographic Surveying

ALTA/ACSM 1992
American Land Title Association/American Congress on Surveying and Mapping/National Society of Professional Surveyors. 1997. "Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys."

American Society for Photogrammetry and Remote Sensing 1990
American Society for Photogrammetry and Remote Sensing. 1990. "ASPRS Accuracy Standards for Large-Scale Maps," Photogrammetric Engineering and Remote Sensing, Vol 56, No. 7, pp 1068-1070.

Bureau of the Budget 1947
Bureau of the Budget. 1947 (17 June). "United States National Map Accuracy Standards," US Bureau of the Budget (now Office of Management and Budget), Washington, DC.

US Bureau of Land Management 1973
US Bureau of Land Management. 1973. "Manual of Instructions for the Survey of the Public Lands of the United States," Technical Bulletin 6, Washington, DC.

Table 11-5. RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP	Survey Accuracy Hor/Vert
<u>DESIGN, CONSTRUCTION, OPERATION & MAINTENANCE OF MILITARY FACILITIES</u>					
Maintenance and Repair (M&R)/Renovation of Existing Installation Structures, Roadways, Utilities, Etc					
General Construction Site Plans & Specs:	1:500	100 mm	50 mm	250 mm	3rd-I
Feature & Topographic Detail Plans	40 ft/in	0.1-0.5 ft	0.1-0.3 ft	1 ft	3rd
Surface/subsurface Utility Detail Design Plans	1:500	100 mm	50 mm	N/A	3rd-I
Elec, Mech, Sewer, Storm, etc	40 ft/in	0.2-0.5 ft	0.1-0.2 ft		3rd
Field construction layout		0.1 ft	0.01-0.1 ft		
Building or Structure Design Drawings	1:500	25 mm	50 mm	250 mm	3rd-I
	40 ft/in	0.05-0.2 ft	0.1-0.3 ft	1 ft	3rd
Field construction layout		0.01 ft	0.01 ft		
Airfield Pavement Design Detail Drawings	1:500	25 mm	25 mm	250 mm	3rd-I
	40 ft/in	0.05-0.1 ft	0.05-0.1 ft	0.5-1 ft	2nd
Field construction layout		0.01 ft	0.01 ft		
Grading and Excavation Plans	1:500	250 mm	100 mm	500 mm	3rd-II
Roads, Drainage, Curb, Gutter etc.	30-100 ft/in	0.5-2 ft	0.2-1 ft	1-2 ft	3rd
Field construction layout		1 ft	0.1 ft		
Recreational Site Plans	1:1000	500 mm	100 mm	500 mm	3rd-II
Golf courses, athletic fields, etc.	100 ft/in	1-2 ft	0.2-2 ft	2-5 ft	3rd
Training Sites, Ranges, and Cantonment Area Plans	1:2500	500 mm	1000 mm	500 mm	3rd-II
	100-200 ft/in	1-5 ft	1-5 ft	2 ft	3rd
General Location Maps for Master Planning	1:5000	1000 mm	1000 mm	1000 mm	3rd-II
AM/FM and GIS Features	100-400 ft/in	2-10 ft	1-10 ft	2-10 ft	3rd
Space Management Plans	1:250	50 mm	N/A	N/A	N/A
Interior Design/Layout	10-50 ft/in	0.05-1 ft			
As-Built Maps: Military Installation Surface/Subsurface Utilities (Fuel, Gas, Electricity, Communications, Cable, Storm Water, Sanitary, Water Supply, Treatment Facilities, Meters, etc.)	1:1000 or 50-100 ft/in (Army); 1:500 or 50 ft/in (USAF)	100 mm / 0.2-1 ft	100 mm / 0.2 ft	250 mm / 1 ft	3rd-I / 3rd

Table 11-5 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP	Survey Accuracy Hor/Vert
Housing Management GIS (Family Housing, Schools, Boundaries, and Other Installation Community Services)	1:5000 100-400 ft/in	10000 mm 10-15 ft	N/A	N/A	4th 4th
Environmental Mapping and Assessment Drawings/Plans/GIS	1:5000 200-400 ft/in	10000 mm 10-50 ft	N/A	N/A	4th 4th
Emergency Services Maps/GIS Military Police, Crime/Accident Locations, Post Security Zoning, etc.	1:10000 400-2000 ft/in	25000 mm 50-100 ft	N/A	N/A	4th 4th
Cultural, Social, Historical Plans/GIS	1:5000 400 ft/in	10000 mm 20-100 ft	N/A	N/A	4th 4th
Runway Approach and Transition Zones: General Plans/Section	1:2500 100-200 ft/in	2500 mm 5-10 ft	2500 mm 2-5 ft	1000 mm 5 ft	3rd-II 3rd
Approach maps	1:5000 (H) 1:1000 (V)				
Approach detail	1:5000 (H) 1:250 (V)				
<u>DESIGN, CONSTRUCTION, OPERATIONS AND MAINTENANCE OF CIVIL TRANSPORTATION & WATER RESOURCE PROJECTS</u> Site Plans, Maps & Drawings for Design Studies, Reports, Memoranda, and Contract Plans and Specifications, Construction plans & payment					
General Planning and Feasibility Studies, Reconnaissance Reports	1:2500 100-400 ft/in	1000 mm 2-10 ft	500 mm 0.5-2 ft	1000 mm 2-10 ft	3rd-II 3rd
Flood Control and Multipurpose Project Planning, Floodplain Mapping, Water Quality Analysis, and Flood Control Studies	1:5000 400-1000 ft/in	10000 mm 20-100 ft	100 mm 0.2-2 ft	1000 mm 2-5 ft	3rd-II 3rd
Soil and Geological Classification Maps	1:5000 400 ft/in	10000 mm 20-100 ft	N/A	N/A	4th 4th
Land Cover Classification Maps	1:5000 400-1000 ft/in	10000 mm 50-200 ft	N/A	N/A	4th 4th

Table 11-5 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP	Survey Accuracy Hor/Vert
Archeological or Structure Site Plans & Details					
(Including Non-topographic, Close Range,	1:10	5 mm	5 mm	100 mm	2nd-I/II
Photogrammetric Mapping)	0.5-10 ft/in	0.01-0.5 ft	0.01-0.5 ft	0.1-1 ft	2nd
Cultural and Economic Resource Mapping	1:10000	10000	N/A	N/A	4th
Historic Preservation Projects	1000 ft/in	50-100 ft			4th
Land Utilization GIS Classifications	1:5000	10000 mm	N/A	N/A	4th
Regulatory Permit Locations	400-1000 ft/in	50-100 ft			4th
Socio-Economic GIS Classifications	1:10000	20000 mm	N/A	N/A	4th
	1000 ft/in	100 ft			4th
Grading & Excavation Plans	1:1000	1000 mm	100 mm	1000 mm	3rd-I
	100 ft/in	0.5-2 ft	0.2-1 ft	1-5 ft	3rd
Flood Control Structure Clearing & Grading	1:5000	2500 mm	250 mm	500 mm	3rd-II
Plans (e.g., revetments)	100-400 ft/in	2-10 ft	0.5 ft	1-2 ft	3rd
Federal Emergency Management	1:5000	1000 mm	250 mm	1000 mm	3rd-I
Agency Flood Insurance Studies	400 ft/in	20 ft	0.5 ft	4 ft	3rd
Locks, Dams, & Control Structures	1:500	25 mm	10 mm	250 mm	2nd-II
Detail Design Drawings	20-50 ft/in	0.05-1 ft	0.01-0.5 ft	0.5-1 ft	2nd/3rd
Spillways & Concrete Channels	1:1000	100 mm	100 mm	1000 mm	2nd-II
Design Plans	50-100 ft/in	0.1-2 ft	0.2-2 ft	1-5 ft	3rd
Levees and Groins: New Construction or	1:1000	500 mm	250 mm	500 mm	3rd-II
Maintenance Design Drawings	100 ft/in	1-2 ft	0.5-1 ft	1-2 ft	3rd
Construction In-Place Volume Measurement	1:1000	500 mm	250 mm	N/A	3rd-II
Granular cut/fill, dredging, etc.	40-100 ft/in	0.5-2 ft	0.5-1 ft		3rd
Beach Renourishment/Hurricane	1:1000	1000 mm	250 mm	250 mm	3rd-II
Protection Project Plans	100-200 ft/in	2 ft	0.5 ft	1 ft	3rd

Table 11-5 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Vertical SI/IP	Contour Interval SI/IP	Survey Accuracy Hor/Vert
Project Condition Survey Reports					
Base Mapping for Plotting Hydrographic Surveys: line maps or aerial plans	1:2500 200-1000 ft/in	10000 mm 5-50 ft	250 mm 0.5-1 ft	500 mm 1-2 ft	N/A N/A
Dredging & Marine Construction Surveys New Construction Plans	1:1000 100 ft/in	2000 mm 6 ft	250 mm 1 ft	250 mm 1 ft	N/A N/A
Maintenance Dredging Drawings	1:2500 200 ft/in	5000 mm 15 ft	500 mm 2 ft	500 mm 2 ft	N/A N/A
Hydrographic Project Condition Surveys	1:2500 200 ft/in	5000 mm 16 ft	500 mm 2 ft	500 mm 2 ft	N/A N/A
Hydrographic Reconnaissce Surveys	-	5000 m 15 ft	500 mm 2 ft	250 mm 2 ft	N/A N/A
Offshore Geotechnical Investigations Core Borings /Probings/etc.	-	5000 mm 5-15 ft	50 mm 0.1-0.5 ft	N/A	N/A 4th
Structural Deformation Monitoring Studies/Surveys					
Reinforced Concrete Structures: Locks, Dams, Gates, Intake Structures, Tunnels, Penstocks, Spillways, Bridges	Large-scale vector movement diagrams or tabulations	10 mm 0.03 ft (long-term)	2 mm 0.01 ft	N/A	N/A N/A
Earth/Rock Fill Structures: Dams, Floodwalls, Levees, etc--slope/crest stability & alignment	(same as above)	30 mm 0.1 ft (long term)	15 mm 0.05 ft	N/A	N/A N/A
Crack/Joint & Deflection Measurements: piers/monoliths--precision micrometer	tabulations	0.2 mm 0.01 inch	N/A	N/A	N/A N/A

Table 11-5 (Contd). RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS

Project or Activity	Target Map Scale SI/IP	Feature Position Tolerance Horizontal SI/IP	Feature Position Tolerance Vertical SI/IP	Contour Interval SI/IP	Survey Accuracy Hor/Vert
REAL ESTATE ACTIVITIES: ACQUISITION, DISPOSAL, MANAGEMENT, AUDIT					
Maps, Plans, & Drawings Associated with Military and Civil Projects					
Tract Maps, Individual, Detailing					
Installation or Reservation Boundaries,	1:1000	10 mm	100 mm	1000 mm	3rd-I/II
Lots, Parcels, Adjoining Parcels, and	1:1200 (Army)				3rd
Record Plats, Utilities, etc.	50-400 ft/in	0.05-2 ft	0.1-2 ft	1-5 ft	
Condemnation Exhibit Maps	1:1000	10 mm	100 mm	1000 mm	3rd-I/II
	50-400 ft/in	0.05-2 ft	0.1-2 ft	1-5 ft	3rd
Guide Taking Lines/Boundary Encroachment	1:500	50 mm	50 mm	250 mm	3rd-I/II
Maps: Fee and Easement Acquisition	20-100 ft/in	0.1-1 ft	0.1-1 ft	1 ft	3rd
General Location or Planning Maps	1:24000	10000 mm	5000 mm	2000 mm	N/A
	2000 ft/in	50-100 ft	5-10 ft	5-10 ft	4th
GIS or Land Information System (LIS) Mapping, General					
Land Utilization and Management, Forestry	1:5000	10000 mm	N/A	N/A	3rd
Management, Mineral Acquisition	200-1000 ft/in	50-100 ft			3rd
Easement Areas and Easement	1:1000	50 mm	50 mm	N/A	3rd
Delineation Lines	100 ft/in	0.1-0.5 ft	0.1-0.5 ft		3rd
HAZARDOUS, TOXIC, RADIOACTIVE WASTE (HTRW) SITE INVESTIGATION, MODELING, AND CLEANUP					
General Detailed Site Plans	1:500	100 mm	50 mm	100 mm	2nd-I/II
HTRW Sites, Asbestos, etc.	5-50 ft/in	0.2-1 ft	0.1-0.5 ft	0.5-1 ft	2nd/3rd
Subsurface Geotoxic Data Mapping	1:500	100 mm	500 mm	500 mm	3-II
and Modeling	20-100 ft/in	1-5 ft	1-2 ft	1-2 ft	3rd
Contaminated Ground Water	1:500	1000 mm	500 mm	500 mm	3rd-II
Plume Mapping/Modeling	20-100 ft/in	2-10 ft	1-5 ft	1-2 ft	3rd
General HTRW Site Plans &	1:2500	5000 mm	1000 mm	1000 mm	3rd-II
Reconnaissance Mapping	50-400 ft/in	2-20 ft	2-20 ft	2-5 ft	3rd

EXPLANATORY NOTES FOR COLUMNS IN TABLE 11-5:

1. Target map scale is that contained in CADD, GIS, and/or AM/FM layer, and/or to which ground topo or aerial photography accuracy specifications are developed. This scale may not always be compatible with the feature location/elevation tolerances required. In many instances, design or real property features are located to a far greater relative accuracy than that which can be scaled at the target (plot) scale, such as property corners, utility alignments, first-floor or invert elevations, etc. Coordinates/elevations for such items are usually directly input into a CADD or AM/FM data base.

2. The feature position or elevation tolerance of a planimetric feature is defined at the 95% confidence level. The positional accuracy is relative to two adjacent points within the confines of a structure or map sheet, not to the overall project or installation boundaries. Relative accuracies are determined between two points that must functionally maintain a given accuracy tolerance between themselves, such as adjacent property corners; adjacent utility lines; adjoining buildings, bridge piers, approaches, or abutments; overall building or structure site construction limits; runway ends; catch basins; levee baseline sections; etc. The tolerances between the two points are determined from the end functional requirements of the project/structure (e.g., field construction/fabrication, field stakeout or layout, alignment, locationing, etc.).

3. Horizontal and vertical control survey accuracy refers to the procedural and closure specifications needed to obtain/maintain the relative accuracy tolerances needed between two functionally adjacent points on the map or structure, for design, stakeout, or construction. Usually 1:10,000 Third-Order (I) control procedures (horizontal and vertical) will provide sufficient accuracy for most engineering work, and in many instances of small-scale mapping or GIS rasters, Third-Order, Class II methods and Fourth-Order topo/construction control methods may be used. Base- or area-wide mapping control procedures shall be specified to meet functional accuracy tolerances within the limits of the structure, building, or utility distance involved for design or construction surveys. Higher order control surveys shall not be specified for area-wide mapping or GIS definition unless a definitive functional requirement exists (e.g., military operational targeting or some low-gradient flood control projects).